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Government Agencies Technology Exchange in Manufacturing (GATE-M)

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**National Institute of Standards
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**U.S. DEPARTMENT OF COMMERCE
Donald L. Evans, Secretary
TECHNOLOGY ADMINISTRATION
Phillip J. Bond, Under Secretary for Technology
NATIONAL INSTITUTE OF STANDARDS
AND TECHNOLOGY
Arden L. Bement, Jr., Director**

Foreword and Disclaimer

This report documents the activities of the Government Agencies Technology Exchange in Manufacturing (GATE-M) from February 2001 to January 2003. This is the period of time from the initial conception of GATE-M to the implementation of the GATE-M Charter.

GATE-M is a joint, interagency activity involving participation from six federal agencies. Representatives of the Manufacturing Engineering Laboratory at the National Institute of Standards and Technology (NIST) have served on the GATE-M Panel during 2001 and 2002 on behalf of the U.S. Department of Commerce, acting as both the initial Panel Chair and initial Panel Secretary.

This document represents the views and perspectives of the NIST representatives to GATE-M. This publication was prepared by United States Government employees as part of their official duties and is, therefore, a work of the U.S. Government and not subject to copyright.

Acknowledgements

The author, who has served as the GATE-M Panel Secretary during its initial development, would like to recognize the following persons who have served as agency representatives to the GATE-M Panel. The contributions of these individuals to the progress and accomplishments of GATE-M and this document are both acknowledged and appreciated.

Howard Bloom, National Institute of Standards and Technology¹
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Dale Hall, National Institute of Standards and Technology
Roger Hayes, National Nuclear Security Administration, U.S. Department of Energy²
George Hazelrigg, National Science Foundation
Stanley Hearn, U.S. Department of Energy³
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Phillip Milstead, National Aeronautics and Space Administration
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¹ Retired from the National Institute of Standards and Technology in 2001.

² Honeywell Federal Manufacturing employee on detail to the U.S. Department of Energy.

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INTRODUCTION

This document describes the initial efforts and results of the Government Agencies Technology Exchange in Manufacturing (GATE-M). GATE-M is striving to represent the voice of federal interests in U.S. manufacturing. While there are a number of efforts and initiatives underway in the U.S. to coordinate various science and technology-related programs within and among federal agencies, GATE-M is unique.

GATE-M is the only current national-level effort that is attempting to specifically and comprehensively focus on manufacturing research and development (R&D) activities conducted at, or funded through, federal agencies across the government.

GATE-M facilitates the exchange of information related to the manufacturing R&D programs of its participating agencies, serving as a forum to identify and create opportunities for the coordination and leveraging of efforts. GATE-M is not a funded federal initiative, nor is GATE-M a policy mandate.

There are six agencies of the federal government participating in GATE-M at the time of the publication of this document. Each of the GATE-M agencies has a distinct and different mission, and each of these agencies includes manufacturing as a major element associated with the conduct of its mission.

The GATE-M effort was initiated to put in place mechanisms to:

- allow the federal agencies with a manufacturing component in their mission to exchange and leverage information about their technical programs;
- coordinate manufacturing R&D programs among federal agencies to facilitate collaboration when it makes sense to leverage resources in the address of particular issues; and
- provide a forum for the agencies to advocate for issues on an interagency, national-level.

This document defines the issues that have been identified for joint address by the GATE-M agencies, including what such joint address of issues means.

The Creation and Initial Operation of GATE-M

GATE-M began in early 2001 when technical managers from six federal agencies with manufacturing as a major component of their missions jointly recognized the need for some type of mechanism or entity that would facilitate a government-wide exchange of information relating to manufacturing R&D. This group agreed that creating opportunities to leverage the knowledge, the programs as appropriate, and perhaps even the resources and capabilities of the various agencies, would pay dividends in national industrial readiness and in the ability of the agencies to efficiently perform their vital missions. It was also agreed that fostering a general sense of cooperation among federal agencies would in turn produce positive outcomes.

GATE-M completed the implementation of a charter in January 2003 to outline the activities and responsibilities of the GATE-M Panel. This GATE-M Panel was formed to identify and integrate requirements, conduct joint program planning, and develop joint strategies for the manufacturing R&D programs conducted by the member agencies. The GATE-M Panel includes representation from six agencies of the federal government, serving as a forum for the exchange and leverage of information among the participating agencies.

As of the publication of this document in 2002, the following agencies participate in GATE-M:

- The U.S. Department of Commerce (DOC), represented by the National Institute of Standards and Technology (NIST)
- The U.S. Department of Defense (DOD), represented by the Office of the Secretary of Defense (OSD)
- The U.S. Department of Energy (DOE) Office of Energy Efficiency and Renewable Energy (EERE)
- The National Aeronautics and Space Administration (NASA), represented by the Marshall Space Flight Center (MSFC)
- The National Nuclear Security Administration (NNSA), a semi-autonomous branch of the U.S. Department of Energy
- The National Science Foundation (NSF), represented by the Directorate for Engineering

The GATE-M Charter

Each of the agencies listed above is a member of the GATE-M Panel, and each has signed the GATE-M Charter as an indication of its commitment to GATE-M. This charter was created to define the types of activities to be undertaken by GATE-M, as well as to document at a high level how the GATE-M Panel would go about performing these activities. The GATE-M Charter provides an official vehicle to recognize the existence of GATE-M, and it also provides the Panel members the authority to work with one another across the agencies in support of the GATE-M objectives.

A copy of the GATE-M charter is included as Appendix A. This Appendix also identifies each agency's charter signatory, who in each instance is a high-level official that serves with authoritative decision-making capacity. NIST has assumed the initial responsibilities of GATE-M Panel Chair and Panel Secretary. The NIST signatory on the charter, the Director of the NIST Manufacturing Engineering Laboratory (MEL), serves as the initial Panel Chair, and the MEL Strategic Relations Manager serves as the Panel Secretary. Each agency has designated a principal to the Panel, who represents the agency in the activities of GATE-M.

The following are the current principals to the GATE-M Panel from each agency.

- DOC/NIST: the Director of MEL. MEL is one of seven NIST Laboratories, and its mission includes the satisfaction of the measurement and standards needs of U.S. manufacturers.
- DOD: the Associate Director for the Office of Technology Transition (OTT), Deputy Under Secretary of Defense (Advanced Systems & Concepts). The OTT manages, among other activities, the DOD Manufacturing Technology Program.
- DOE EERE: the Manager of the Office of Industrial Technologies (OIT). OIT is one of EERE's primary points of interface with U.S. industry that has been very active in the development of industry roadmaps.
- DOE NNSA: the Program Manager for the Advanced Design and Production Technologies (ADAPT) Campaign. ADAPT supports applied science, process, and manufacturing technology development efforts at three National Laboratories (Sandia, Lawrence Livermore, and Los Alamos) and four production plants (Kansas City, Pantex, Savannah River, and Y-12).
- NASA: the Manager of the MSFC National Center for Advanced Manufacturing (NCAM). MSFC and the NCAM conduct a significant amount of the manufacturing R&D activities within NASA.
- NSF: the Manufacturing Machines and Equipment Program Director in the Directorate for Engineering. The Directorate for Engineering includes two Divisions with a major focus on manufacturing – the Division of Design, Manufacture, and Industrial Innovation; and the Division of Engineering and Education Centers.

THE GATE-M PROCESS

2001 Program Review

In May 2001, the GATE-M participant agencies held a two-day workshop in Crystal City, Virginia, to discuss their manufacturing science and technology programs. This manufacturing technology exchange was a vehicle by which each of the agencies highlighted its most important activities and priorities, in turn increasing the participants' awareness of the breadth and depth of the manufacturing R&D programs across the federal government. The purpose of the meeting was to achieve a better collective understanding of the work being done, and to explore opportunities for cooperation to accelerate progress toward common goals. Individual programs and projects of each agency were included among the presentations, and several technical discussions and interactions resulted.

The topics that were presented and discussed during this workshop are contained in Appendix B.

This event was groundbreaking in that an exchange such as this had not previously occurred at this level and in this manner. This workshop was unique because six separate federal agencies presented research activities and programs to one another in the presence of technical managers, engineers, and scientists, and without the involvement of policy

makers, budget monitors, or even concerned industry entities. This was a forum in which there was no formal review process or program critiquing. This was purely an information exchange forum for the purpose of making the agency principals and line-level manufacturing decision-makers better aware of the research activities and programs of other agencies.

The Focus of the GATE-M Panel

Since the successful and unique 2001 workshop, GATE-M has focused on identifying the priority manufacturing technical areas from each of the agencies. The intent of this process was to define a set of issues for the GATE-M agencies to address jointly. The notion of what it should mean for six different agencies to address a set of issues jointly was also detailed as specifically as possible.

Each agency submitted to the Panel a list of its most important manufacturing-related priorities, representing high-level, agency-wide issues that are critical to the mission function of each agency.

The 37 issues submitted by the agencies are listed alphabetically by agency below.

- DOC/NIST
 - Homeland Security
 - Intelligent Systems
 - Manufacturing Processes and Equipment
 - Manufacturing Systems Interoperability
 - Nanotechnology
 - *Système International* (SI) Metrology
- DOD
 - Affordable MEMS for Missiles and Munitions
 - Assured Supply Chain Responsiveness
 - Composites Affordability Initiative – Aircraft
 - Enhanced Mission Electronics Cost of Ownership
 - Integrated Survivable Composite Structures
 - Joint Engine Sustainment Initiative
 - Manufacturing Technology for Infrared (IR) Cooled and Uncooled Staring Sensors
 - Metalworking Affordability Initiative for Castings and Forgings
- DOE EERE
 - Creation of the New Domestic BioIndustry
 - Dramatically Reduced or Ended U.S. Dependence on Foreign Oil
 - Increased Efficiency and Reduced Energy Intensity of Industry
 - Increased Efficiency and Reliability of Electricity Generation, Delivery, and Use
 - Increased Efficiency of Buildings and Appliances
 - Increased Visibility and Deployment of Renewable Energy

- DOE NNSA
 - Enterprise Integration
 - Integrated Product and Process Design
 - Integrated Product and Process Design / Agile Manufacturing
 - Micro-Assemblies / Microelectronics
 - Need-to-Know Architecture
- NASA
 - Aerospace Manufacturing Infrastructure
 - Composites Processing
 - Emerging Technologies (Nanotechnology)
 - Intelligent Manufacturing
 - Manufacturing Engineering Education
 - Metallic Processing
- NSF
 - Academic-Industry Partnerships
 - Curriculum and Educational Innovation
 - Environmentally Benign Manufacturing
 - Information for Academic Researchers
 - Manufacturing Enterprise Systems
 - Nanomanufacturing

These 37 issues were grouped into the following eight aggregate areas, which are listed below alphabetically.

- Environmentally Focused Technologies and Processes
- Homeland / National Security
- Intelligence in Manufacturing
- Manufacturing Education
- Manufacturing Process Development – Metals and Composites
- Manufacturing Quality and Reliability (Measurement and Testing)
- Nano- / Micro-Scale Systems and Technologies
- Supply Chain / Systems Integration and Interoperability

THE GATE-M JOINT ISSUES

From the issue submissions and aggregations, the GATE-M Panel identified those issues that would be jointly addressed by the agencies. As the Panel vetted the aggregated issues, several things came into focus.

First, each agency has a distinct and quite different mission, in terms of both mission focus, as well as the characteristics of the missions. To elaborate, several of the agencies are basically product-focused, whereas others are focused on issues that are more infrastructural in nature. For example, a product-focused agency such as the DOD is concerned with the development and production of ships, tanks, aircraft, missiles, and

other weapon systems. The manufacturing issues of concern to an agency such as this must in a basic and direct sense relate to how these products can be made better, cheaper, faster. On the other hand, an infrastructure-focused agency such as NIST is concerned with technology and other issues that enhance U.S. productivity and improve the nation's standard of living in a broader sense, without the necessity to tie issues to specific products.

Second, the notion of issue prioritization was something that was essentially meaningless. Each agency submitted its highest priority manufacturing issues, which were grouped into the aggregate areas being examined. These aggregate areas were actually collections of priorities. Because of the differences in the mission orientation and focus of the various agencies, each agency basically viewed each issue in a very different manner. The Panel, therefore, did not see compelling reason to attempt to weigh any priority area as more important than any other. Consequently, the Panel conducted no ranking or voting process to prioritize the issues.

Finally, it became clear to the Panel that identifying commonality of interest in the aggregate areas across the agencies was more important than attempting to achieve consensus prioritization. Identifying commonality of interest among the issues allowed each agency to maintain its own priorities without compromise. This also identified those areas where multiple agencies were either currently working programs relevant to the issue, or were quite interested in starting new efforts.

It was this parameter – commonality of interest among the agencies – that led the Panel to select the following areas as the initial issues to be jointly addressed by the GATE-M Panel:

1. **Intelligence in Manufacturing (near-term)**
2. **Nano- / Micro-Scale Systems and Technologies (longer term)**

These two issues were both identified as areas where all the participating GATE-M agencies had activity underway or felt they could benefit from new activity, and they were identified as areas that all the agencies agreed they wanted to pursue further.

Intelligence in Manufacturing

Intelligence in Manufacturing represents an enabling, crosscutting technology area that is potentially transformative in terms of how manufacturing might be conducted in the future. The area is gaining interest across multiple industry sectors for a variety of reasons, and all of the GATE-M agencies have programs currently in place that directly address this area or are directly relevant. This fact led the Panel to consider this area as one where GATE-M could immediately begin to make an impact through joint address across the agencies.

The Panel also felt strongly that significant opportunity exists for manufacturing R&D to make a difference in the area of Intelligence in Manufacturing. For example, this area

could have a big potential impact on supply chain cost, quality, and reliability. Additionally, the manufacturing community is just beginning to tap the capabilities for manufacturing that are afforded by intelligent, open architecture control. There could also be significant opportunities for agencies with product-oriented missions to apply technology developed elsewhere (i.e., at another GATE-M agency) to specific manufacturing problems in their product-specific domains.

Nano- / Micro-Scale Systems and Technologies

Nano- / Micro-Scale Systems and Technologies represents an area that is not highly mature, but where the Panel also felt there existed good opportunity for manufacturing R&D to make a difference. It is the relative lack of maturity that caused the Panel to label this as an issue for address in a longer-term basis. This is a very important, emerging science and technology area that promises significant and broad impact to the future of U.S. manufacturing, as well as the U.S. economy and society on a large scale. This is an area with many manufacturing and systems issues, where GATE-M could likely find several ways to pull the missions of its participating agencies together. A number of electrical and mechanical application areas exist or are being investigated, and the Panel felt that assembly areas and measuring techniques and tools could be fertile topics to pursue. The Panel also stressed its need to not stray into science, but to stay focused on manufacturing technology. The Panel also recognized the need to coordinate the GATE-M activities in this area with the activities and committees of the National Nanotechnology Initiative, which is a multi-agency federal initiative being overseen by the White House Office of Science and Technology Policy. More information about this initiative can be obtained at www.nano.gov.

It should be noted that, while Intelligence in Manufacturing and Nano- / Micro-Scale Systems and Technologies were selected as the initial issues to be addressed jointly by GATE-M, all eight of the aggregate areas discussed by the Panel remain as viable candidates for examination at a future time. Each of these issues is based on the agencies' manufacturing related priorities, and is in turn a priority in its own right.

GATE-M Joint Address of Issues

With the selection of these two initial issues for GATE-M to jointly address, the Panel also defined what it means for GATE-M to jointly address an issue, as well as how GATE-M should go about doing this. The joint address of issues by GATE-M means that two primary types of activities will be conducted by GATE-M with respect to these defined issues:

1. information exchange among the GATE-M agencies
2. advocacy by the GATE-M agencies with respect to the issues

With respect to information exchange, GATE-M will approach the joint address of the identified issues in the following manner.

- GATE-M plans to conduct interagency “program reviews” in the specific areas for the purpose of communicating among the participating agencies what each agency is currently conducting or is interested in pursuing in the particular area and to explore opportunities for collaboration. These “program reviews” would be modeled after the May 2001 workshop described earlier in this document.
- GATE-M may jointly sponsor workshops to address the specific areas. These workshops could include technical area experts from both GATE-M agencies, as well as industry or other non-GATE-M entities.
- GATE-M may promote and sponsor the development of roadmaps in the specific technical areas.
- GATE-M may do multi-agency brainstorming where agencies could potentially serve as technical consultants to other GATE-M agencies to address areas of specific interest to a particular agency.
- The constituent bases of each agency may be merged with those of the other agencies to facilitate new opportunities and application areas for the agencies.

With respect to GATE-M advocacy, GATE-M will approach the joint address of the identified issues in the following manner.

- On behalf of the participating agencies, GATE-M plans to issue joint white papers or position papers that represent interagency advocacy positions with respect to the particular issues.
- GATE-M will consider how its advocacy for a particular issue could provide the foundation or framework for a national initiative in manufacturing. In this context, GATE-M will actively pursue the communication of GATE-M positions to other, national-level entities pursuing national manufacturing initiatives and interagency activities.
- GATE-M may decide to issue a joint “challenge,” where sponsorship would be obtained to promote the issuance of some type of reward to the research community for tackling and solving an exceptionally difficult technical challenge that would be defined by GATE-M and be related to the particular, identified issues.
- The GATE-M agencies may pursue the potential development of joint Small Business Innovative Research topics and awards, if appropriate.
- The GATE-M agencies may jointly support studies by authoritative third parties to address technical issues.

SUMMARY

GATE-M began in 2001 to address the need for an entity at the national level to facilitate information exchange and coordinate leveraging opportunities relating to the manufacturing R&D programs of the various federal agencies that include manufacturing as a major component of their mission. GATE-M has progressed significantly from its inception to its current state where a set of manufacturing-related priority areas have been identified for joint address by the participating agencies.

GATE-M has implemented a charter that includes the support of six separate agencies of the federal government. The GATE-M Charter is important because it defines the types of activities to be undertaken by GATE-M. The GATE-M Charter provides an “official” vehicle that documents and recognizes the existence of GATE-M. The GATE-M Charter also provides the members of the GATE-M Panel the authority to work with one another across the agencies in support of the GATE-M objectives.

GATE-M has selected Intelligence in Manufacturing and Nano- / Micro-Scale Systems and Technologies as the initial two issues that it will address jointly. Joint address of these two issues means that GATE-M will pursue a number of mechanisms to promote an information exchange among the participating agencies in these areas. Joint address of these issues also means that GATE-M will advocate for them in a representative manner on behalf of the participating agencies.

FUTURE DIRECTIONS

During 2003, GATE-M plans to conduct program reviews relating to the two identified issues. GATE-M also anticipates the development and circulation of position papers relating to these issues. GATE-M will continue to increase its visibility within the national manufacturing community, and GATE-M will conduct outreach to other, national-level entities that are pursuing national manufacturing initiatives and interagency activities. As GATE-M progresses, the priorities of its participating agencies should also be re-examined to update and expand the set of issues that are jointly addressed.

A stretch goal that GATE-M has defined for itself is to reach a point of maturity in the near term future where GATE-M could serve and be widely recognized as the voice of federal manufacturing. The future activities of GATE-M will be oriented toward the realization of this goal.

APPENDIX A: The GATE-M Charter

Charter

Government Agencies Technology Exchange in Manufacturing (GATE-M) Panel

I. PURPOSE AND SCOPE

- A. The purpose of the Government Agencies Technology Exchange in Manufacturing (GATE-M) Panel is to identify and integrate requirements, conduct joint program planning, and develop joint strategies for the manufacturing research and development programs conducted by the member agencies within the Panel. The GATE-M Panel will serve as a forum for the exchange and leverage of information among the participating agencies.
- B. The scope of the GATE-M Panel is primarily limited to those manufacturing technologies that contribute to the mission or benefit of two or more of the agencies. The Panel will not consider those manufacturing issues that are exclusively tied to the mission of a single agency, unless specifically requested to do so by that agency.

II. ROLE OF THE PANEL

- A. Establish information exchange processes among member and non-member government agencies, private industry, academia, and professional associations. These processes shall include supporting annual member conferences such as the Defense Manufacturing Conference, and developing and maintaining a GATE-M web site.
- B. Conduct comprehensive reviews and assessments of manufacturing research and development issues being addressed by the agencies' strategic planning processes to identify joint planning opportunities for increased cooperation in research, development, implementation of technological products, and leveraging of funding with the private sector and other government agencies.
- C. Present an annual review of the manufacturing programs within the member agencies to the members of the Panel. During the reviews, identify opportunities for leveraging and sharing resources among the agencies, including the exchange of personnel.
- D. Encourage the integration and coordination of manufacturing requirements and programs into multi-agency initiatives with manufacturing technology-related requirements and programs.

III. ORGANIZATION AND MANAGEMENT

- A. The GATE-M Panel will serve as a management panel with representatives from each of the participating agencies. It will report status of activities within the panel to the various agencies.
- B. The GATE-M Panel shall include at least one member (one of whom will be designated principal member) from each agency, who is a senior technical manager, and who can represent the agency within the scope of the GATE-M Panel. The chairmanship of the GATE-M Panel shall initially be the representative from Department of Commerce, National Institute of Standards and Technology. Rotation of chairmanship shall be addressed on an annual basis and agreed to by the Panel representatives.
- C. The responsibilities of the GATE-M Panel Chairman will include: serving as the main interface between the GATE-M Panel and outside agencies interested in the activities of the Panel, conducting the GATE-M Panel meetings, developing a consensus on pertinent issues, ensuring that appropriate meeting minutes are recorded and published, orchestrating briefings and papers representing the views of the panel, and maintaining an environment which fosters continuous improvement, cooperation, innovation and free information exchange.
- D. The GATE-M Panel will establish subpanels and working groups as needed. Subpanel functions could include conducting reviews of manufacturing technical programs, providing technical advice to the Panel, and exploring specific technology areas, such as security issues for manufacturing, for example.
- E. Each agency's participation in the GATE-M Panel will be at the expense of the individual agency, but no agency is required to obligate funds for the GATE-M Panel. Support of other expenses will be negotiated among the agencies on an ad hoc basis.
- F. Any GATE-M Panel agency participant may terminate its participation in the GATE-M Panel by providing written notice to the other Panel members.
- G. The term of this charter is for an indefinite period. The charter shall, however, be reviewed at least every two years to insure that it is still fulfilling its purpose, and to make any necessary revisions.

IV. INTERFACES

- A. The GATE-M Panel will interface and coordinate its activities with other manufacturing research teams, experts, or panels (e.g., the Joint Defense

Manufacturing Technology Panel, the Board on Manufacturing and Engineering Design, industry manufacturing consortia, etc.) as appropriate.

- B. Representatives from organizations such as key industry consortia, trade associations and professional societies may be invited to provide the GATE-M Panel with presentations and information about specific topics.
- C. Technical experts from industry, government agencies, and academia may be invited to provide subpanels and working groups with presentations and information about specific technical topics.

V. MEMBERSHIP

- A. The membership of the GATE-M Panel is open to any U.S. federal agency that has a program in manufacturing research and development.
- B. The following agencies agree to participate in the GATE-M Panel:

Department of Commerce National Institute of Standards and Technology

Dale Hall
Director, Manufacturing Engineering Laboratory

Department of Defense

John B. Todaro
Director, Technology Transition
Office of the Director, Defense Research and Engineering

Department of Energy

Richard Moorer
Deputy Assistant Secretary, Technology Development
Energy Efficiency and Renewable Energy

Department of Energy National Nuclear Security Administration

Julianne F. Levings
Program Manager, Advanced Design and Production Technologies Campaign

National Aeronautics and Space Administration

A. G. Stephenson
Director, Marshall Space Flight Center

National Science Foundation

Esin Gulari
Assistant Director for Engineering

APPENDIX B: 2001 GATE-M Program Review

The following topics were presented and discussed by the GATE-M agencies during the May 2001 program review that was held in Crystal City, Virginia.

- Department of Commerce Presentations
 - Manufacturing at NIST
 - NIST Precision Engineering
 - NIST Manufacturing Metrology
 - NIST Intelligent Systems
 - NIST Manufacturing Systems Integration
- Department of Defense Presentations
 - DOD Science and Technology / Manufacturing Technology Program
 - Metals Processing / Optics Manufacturing
 - Electronics Processing and Fabrication
 - Micro-Electro-Mechanical Systems (MEMS)
 - Advanced Manufacturing Enterprise
 - Small and Medium Enterprise Program
 - Integrated Manufacturing Simulation for Affordability
- Department of Energy Presentations
 - Office of Industrial Technologies Industries of the Future
 - Advanced Design and Production Technologies Campaign and Manufacturing
 - Process Development
 - Enterprise Integration
 - National Nuclear Security Administration Product Realization Process
 - Integrated Product and Process Development / Agile Manufacturing
 - Feature-Based Manufacturing
- NASA Presentations
 - NASA Manufacturing
 - NASA Technology Transfer
 - National Center for Advanced Manufacturing
- National Science Foundation Presentations
 - NSF Manufacturing Research
 - NSF Manufacturing Research Opportunities

